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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# MSC INTERNAL NOTE NO. 67-FM-17

31 JANUARY 1967

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# OPERATIONAL SUPPORT PLAN FOR THE REAL-TIME AUXILIARY COMPUTING FACILITY

By Flight Analysis Branch, NASA/MSC, and
Mission Operations Section, TRW Systems





MISSION PLANNING AND ANALYSIS DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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# FOREWORD

This Operational Support Plan describes and documents the basic activities of the Real Time Auxiliary Computing Facility and outlines the types of support this facility provides. In addition to this basic plan, an individual flight annex containing detailed information about each mission will be published under separate cover.

The Operational Support Plan represents the end result of a joint effort between TRW and MSC-MPAD. TRW participation in this effort is done under MSC/TRW Task AA-3, Contract NAS 9-4810.

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ILLUSTRATIONS

## NOMENCLATURE

| | |
|---|---|
| ABORT | The Abort to an Optimum Return Trajectory Program |
| ACR | Auxiliary Computing Room |
| AEG | Analytic Ephemeris Generator Program |
| AMS | Apollo Mission Simulator |
| ARMP | Apollo Reference Mission Program |
| ARRS | Apollo RTACF Rendezvous System Program |
| CAD | Computation and Analysis Division |
| DCS | Direct Couple System |
| DMT | Detailed Maneuver Table |
| FAB | Flight Analysis Branch |
| FCD | Flight Control Division |
| FDSSR | Flight Dynamics Staff Support Room |
| FOD | Flight Operations Directorate |
| FSS | Flight Studies Section |
| GOST | Guidance Officer's Optics Support Table |
| GPMT | General Purpose Maneuver Table |
| I/O | Input/Output |
| IMU | Inertial Measurement Unit |
| KSC | Kennedy Space Center |
| MMDB | Mission Modular Data Book |
| MOCR | Mission Operations Control Room |
| MPAD | Mission Planning and Analysis Division |
| MPT | Mission Planning Table |
| MSC | Manned Spacecraft Center |
| MSS | Mission Support Section |

NOMENCLATURE (Continued)

| | |
|---|---|
| NORAD | North American Air Defense Command |
| OSP | Operational Support Plan |
| OT | Operational Trajectory |
| PIT | Parameter Iteration Technique Mode |
| RPT | Rendezvous Planning Table |
| RT | Reference Trajectory |
| RTACF | Real Time Auxiliary Computing Facility |
| RTCC | Real Time Computer Complex |
| SG-GEM | MSC - General Electric Missile and Satellite Program |
| SOW | Support Operations Wing |
| SPS | Service Propulsion System |
| TSC | Trajectory Support Chief |

## DEFINITIONS

Program — As used in this report refers to a large generalized simulation computer routine which can be configured by means of input data to satisfy a number of RTACF requirements.

Processor — As used in this report means:

a) A computer routine written to satisfy only one RTACF requirement; or

b) A set of input data to a generalized simulation computer routine which configures that program to satisfy only one RTACF requirement.

# 1. INTRODUCTION

## 1.1 PURPOSE

This Operational Support Plan (OSP) describes and documents the present activities of the Real Time Auxiliary Computing Facility (RTACF) and outlines the types of support which are provided. It may serve as a reference for potential users of the RTACF as well as to those who may be called upon to assist in RTACF operations.

To accomplish the above, the OSP indicates the functions of the RTACF and the present procedures being followed in their execution. These functions and procedures have evolved from those used during Projects Mercury and Gemini and are constantly subject to refinement and revision in order to make the RTACF more effective. This OSP will be revised to reflect any changes that are made.

## 1.2 METHOD OF PRESENTATION

The OSP consists of a basic plan and a flight annex. Those activities which do not change on a flight-to-flight basis are described in the basic document which represents the general procedures and capabilities of the RTACF. Those support functions which are peculiar to a specific mission, as well as explanatory information pertaining to only one mission, are included in the flight annex for that mission. Normally the basic plan, which is of general interest, will be distributed widely. The flight annex, which contains detailed information about a particular mission, will be published approximately 6 weeks before each flight and will have a limited distribution.

# 2. RTACF FUNCTIONS AND USE

## 2.1 GENERAL

The basic function of the RTACF is to support the flight control team and to help meet the MSC responsibilities for inflight operational computing support during a mission. Currently, RTACF activity is primarily trajectory related and supports the flight dynamics group (Flight Dynamics Officer, Retrofire Officer, and Guidance Officer) of the flight control team. However, the capability to support other flight control groups exists in the RTACF and will be further developed for future missions.

The name Real Time Auxiliary Computing Facility itself implies that the RTACF assists in the real time computing operation. It is in this sense an extension of the Real Time Computer Complex (RTCC) because it performs computations that cannot or should not be performed by the RTCC. The size and complexity of the RTCC creates a lack of flexibility which results in the need for the flexible auxiliary type of operational support that is the main characteristic of the RTACF.

## 2.2 RTACF FUNCTIONS

All RTACF functions are directly dependent upon the requirements that have been placed on it by organizational elements within MSC. Details of how an organizational element may receive operational computing support are covered in Section 6 of this document. Currently, the specific RTACF functions can be grouped under one of the following three categories.

### 2.2.1 Real Time Requirements Not Included in the RTCC, but Deemed Necessary for Mission Success

There are always a number of computing requirements deemed necessary for mission success which for one reason or another are not included in the RTCC. Among these are the following:

a) Requirements Identified Late in the Planning Cycle - Because of the long lead time necessary to develop, implement, and test the complete RTCC system, the requirements for the RTCC support must be identified early in the planning cycle. When these requirements are not completely defined in time to allow adequate RTCC implementation and checkout, the RTACF may be used to perform the necessary computations.

b) Requirements Which Demand Greater Flexibility Than Exists in the RTCC - The primary function of the RTCC is to perform computations for the basic mission, and as a result there are limitations as to what it can do. For example, once maneuvers are scheduled in the RTCC program it is not operationally feasible for the RTCC to be used to study off-nominal or alternate missions. In contrast the RTACF can and does alter planned maneuvers to compute the effects of deviations and non-nominal performance. Also the RTCC can only be used to plan ahead 22 revolutions while the RTACF can be used to plan as far into the future as desired.

c) Requirements Which Are Not Time Critical - There are several computational support functions needed during a mission which do not require an immediate display of outputs to the flight control team and are not economically feasible from a time standpoint for inclusion into the RTCC program. These functions when possible are performed by the RTACF. A good example of this type of support is the calculation of contingency retrofire times (block data).

### 2.2.2 Requirements to Provide Independent or Added Real Time Support to the RTCC

One of the functions of the RTACF consists of confirming data produced by the RTCC during both real time and in preflight program verification activities. This function is performed in instances where the accuracy of the RTCC results can critically affect mission success. The RTACF can in many instances provide more detailed information than is available from the RTCC displays.

### 2.2.3 Requirements for Trajectory Limit Lines and Mission Constants

The Mission Support Section (MSS), which has the responsibility of coordinating and running the RTACF, also serves as the coordinating group for the collection of approved mission constants and trajectory limit lines used by the RTCC, the RTACF, and the flight simulators.

### 2.3 TYPICAL USES OF THE RTACF

In order to provide a better understanding of the type of support the RTACF provides the flight control team, this section outlines some typical uses of the RTACF.

#### 2.3.1 Prelaunch Support

The RTACF can perform any of the following prelaunch calculations:

a) Evaluate the effects of last minute changes in aerodynamics or weight.

b) Make engineering units to octal conversion runs for spacecraft software checks.

c) Calculate spacecraft plane change and phasing launch windows (backup to RTCC).

d) Calculate a recommended lift-off time for missions requiring a rendezvous (backup to RTCC).

e) Make any last minute trajectory check runs desired by the flight control team.

f) Calculate the effects of actual launch day winds on possible Mode I launch aborts (aborts with the Launch Escape Tower).

#### 2.3.2 Support During Launch

During the launch vehicle powered flight phases, the RTACF can compute (usually after the fact) the required backup data to support all launch abort modes. This includes the capability to calculate:

a) Entry trajectories with any desired lift profile (backup to RTCC).

b) The SPS velocity required to restrict the entry landing range to a specific value (backup to RTCC).

c) The SPS velocity required to place the spacecraft in an acceptable orbit (backup to RTCC).

d) Impact points after an abort.

#### 2.3.3 Support During Orbital Flight

Most of the RTACF activity takes place once a spacecraft achieves orbit. In general the RTACF performs the following tasks:

a) Calculates data for the Public Affairs Officer. This usually consists of orbital elements, tracking data over a particular site, sequence of events, etc.

b) For orbital maneuvers, the RTACF can duplicate the RTCC displays of the General Purpose Maneuver Table (GPMT), the Mission Planning Table (MPT), and the Detailed Maneuver Table (DMT). For rendezvous missions the RTACF can also duplicate the Rendezvous Planning Table (RPT). These displays usually present all the data required to perform a maneuver as well as the orbital parameters after the specified maneuver has been performed. If desired, the RTACF can provide more detailed information about a maneuver than is available from these RTCC displays. The processors used to calculate these data are also used to perform alternate mission studies during real time. The RTACF can also evaluate how well a maneuver has been performed.

c) The RTACF can do atmospheric drag studies (K factor studies).

d) The RTACF can duplicate the RTCC display of the Guidance Officer's Optics Support Table (GOST). This table is used to evaluate IMU alignments and provide ground support for optical sighting to attain backup attitude orientations.

e) Calculate new spacecraft aerodynamics as the spacecraft center-of-gravity location changes.

f) Calculate and confirm command loads to be sent to the spacecraft.

g) On a continuing basis, the RTACF computes the deorbit block data which is passed to the spacecraft. These are contingency retrofire times.

h) The RTACF also verifies the RTCC deorbit data for the daily GO/NO-GO areas.

i) To facilitate real time mission planning or crew activity scheduling, the RTACF can calculate, as required, radar tracking data, spacecraft lighting, spacecraft lifetime, look angles to or from specified ground stations or celestial targets, ground track data, closest approach data between a spacecraft and a ground station, radiation dosage for a specified period of time, or perform relative motion studies.

### 2.3.4 End-of-Mission Entry Support

At all times during a mission the RTACF is prepared to duplicate the data presented on the RTCC Retrofire Officer Deorbit Digitals display, simulate a guided entry, and compute all of the backup guidance quantities necessary to steer the spacecraft to a specified landing point. The RTACF can also produce entry ground tracks, entry sequence of events, and post-retrofire footprint displays.

# 3. GENERAL DESCRIPTION OF THE RTACF

## 3.1 GENERAL

The RTACF is composed of multiple computer facilities which are utilized by engineers located in the Auxiliary Computing Room (ACR).

## 3.2 DESCRIPTION OF THE ACR

The ACR is the operational center established for the management and control of the RTACF during pre-mission checkout, simulations, and mission support. It is located in the Support Operations Wing (SOW) of the Mission Control Center (Building 30), Room 3052-C. The physical layout of the ACR is shown in Figure 1 and a description of the major ACR facilities and their utilization is given below.

### 3.2.1 Furnishings

The ACR is equipped with the necessary standard office equipment to support the assigned personnel.

### 3.2.2 Communications

The ACR contains three call directors which are used by the ACR Chief and the ACR engineers (when required) to communicate with the Flight Dynamics Staff Support Room (FDSSR). These call directors are connected to both Mission Operations Control Rooms. The communication loops available on these call directors include the GOSS Conference, Flight Director, RTCC Dynamics, Flight Dynamics, ACR Conference, SSR Conference, and Maintenance and Operations. Besides these call directors, there are also six monitor jacks available for use by the ACR engineers for monitoring communication loops. There is also one loudspeaker connected to the ACR Chief's call director which can be utilized if desired.

### 3.2.3 ACR TV Display Monitors

Suspended from the ACR ceiling are five TV display monitors. These monitors are used by the ACR personnel to obtain operational information. The displays presented on these monitors are controlled by the RTACF personnel in the FDSSR. The two left monitors are slaved to the second floor FDSSR while the two right monitors are slaved to the third floor

FDSSR. The middle monitor can be switched to either floor by the ACR Chief but the displays presented are still controlled from the FDSSR. This ability to talk to and observe displays from the FDSSR gives the RTACF the ability to support both Mission Operations Control Rooms simultaneously.

### 3.2.4 Opaque Televiewer

An opaque televiewer is one method used to relay trajectory and systems information generated in the RTACF to the flight control team. Channel 35 has been assigned to this camera.

### 3.2.5 Keypunch Machine

The keypunch machine is used to prepare inputs to the RTACF processors.

### 3.2.6 ACR Teletype

The ACR teletype is utilized for receiving state vectors generated in the RTCC. The same vector information is transmitted concurrently to the UNIVAC 1004 located in an adjacent room which outputs the data on punched cards in the correct format so that it can be input directly into the RTACF processors.

## 3.3 DESCRIPTION OF THE PRIMARY COMPUTER FACILITY

The primary computer used to support the RTACF is an IBM 7094 Mod I computer, located in Room 3049 adjacent to the ACR. This 7094 is able to handle jobs written in FORTRAN II, FORTRAN IV, and machine language. The 7094 also has on-line input/output (I/O) capabilities (card reader and printer). An IBM 360/30 computer adjacent to the 7094 is used for off-line I/O duties. The present configuration of the primary computer facility is shown in Figure 2.

## 3.4 DESCRIPTION OF THE BACKUP IBM 7094/7040 DIRECT COUPLE SYSTEM

The principal backup computer facility used to support the RTACF is an IBM 7094/7040 system coupled together (DCS) located in the second floor computer area of Building 12. The 7040 handles all I/O and job scheduling for the 7094 and leaves the 7094 free to perform computations only. Also, remote site I/O can be handled through the use of a UNIVAC 418 computer which is linked to the DCS. The DCS is able to handle every job the primary 7094 computer handles but does not have a capability for on-line card reading or on-line printing. Therefore, results are printed only after a job is completed. The present configuration of this computer facility is shown in Figure 3.

## 3.5 DESCRIPTION OF THE BACKUP IBM 7094 COMPUTER FACILITY IN THE RTCC

One of the RTCC IBM 7094 Mod II computers is sometimes used as a backup to the RTACF. The use is on a non-interference basis with real-time operations. The configuration is similiar to the primary 7094 as described in Section 3.3. It has on-line card input capabilities as well as on-line printer output capability and can perform the same jobs as the primary machine.

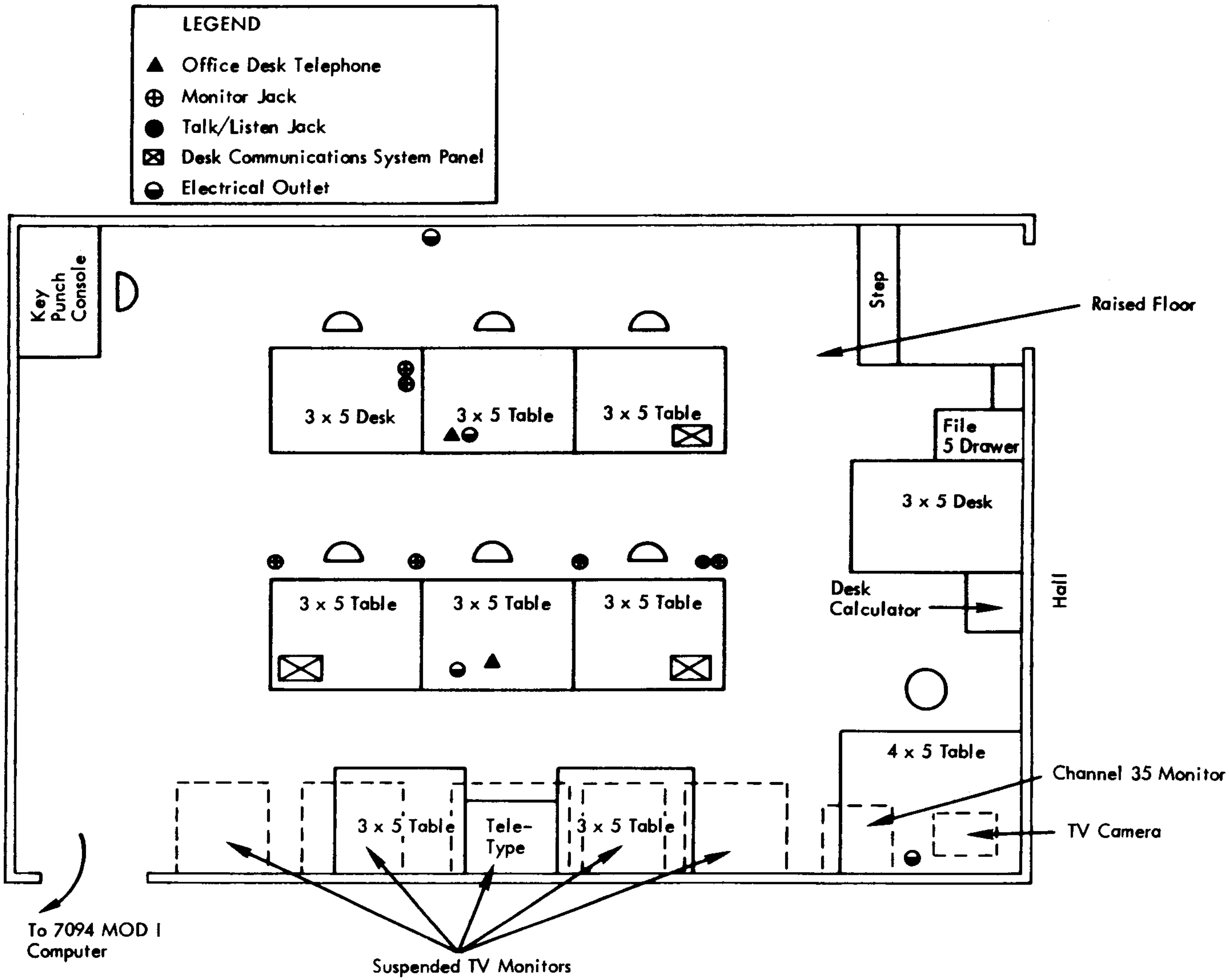


Figure 1. Auxiliary Computing Room Floor Plan, Room 3052-C, Building 30

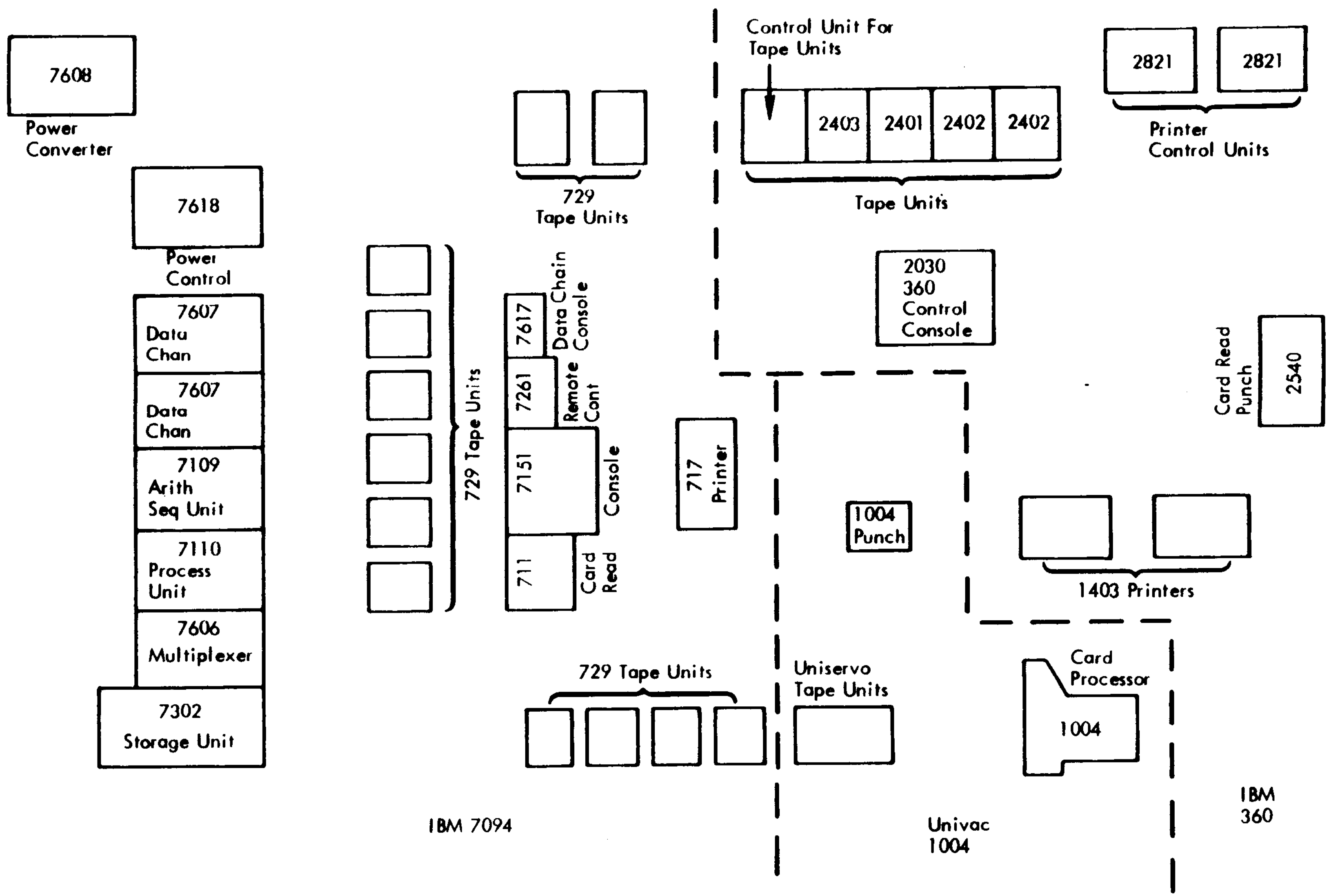


Figure 2. RTACF Primary Computer Facility

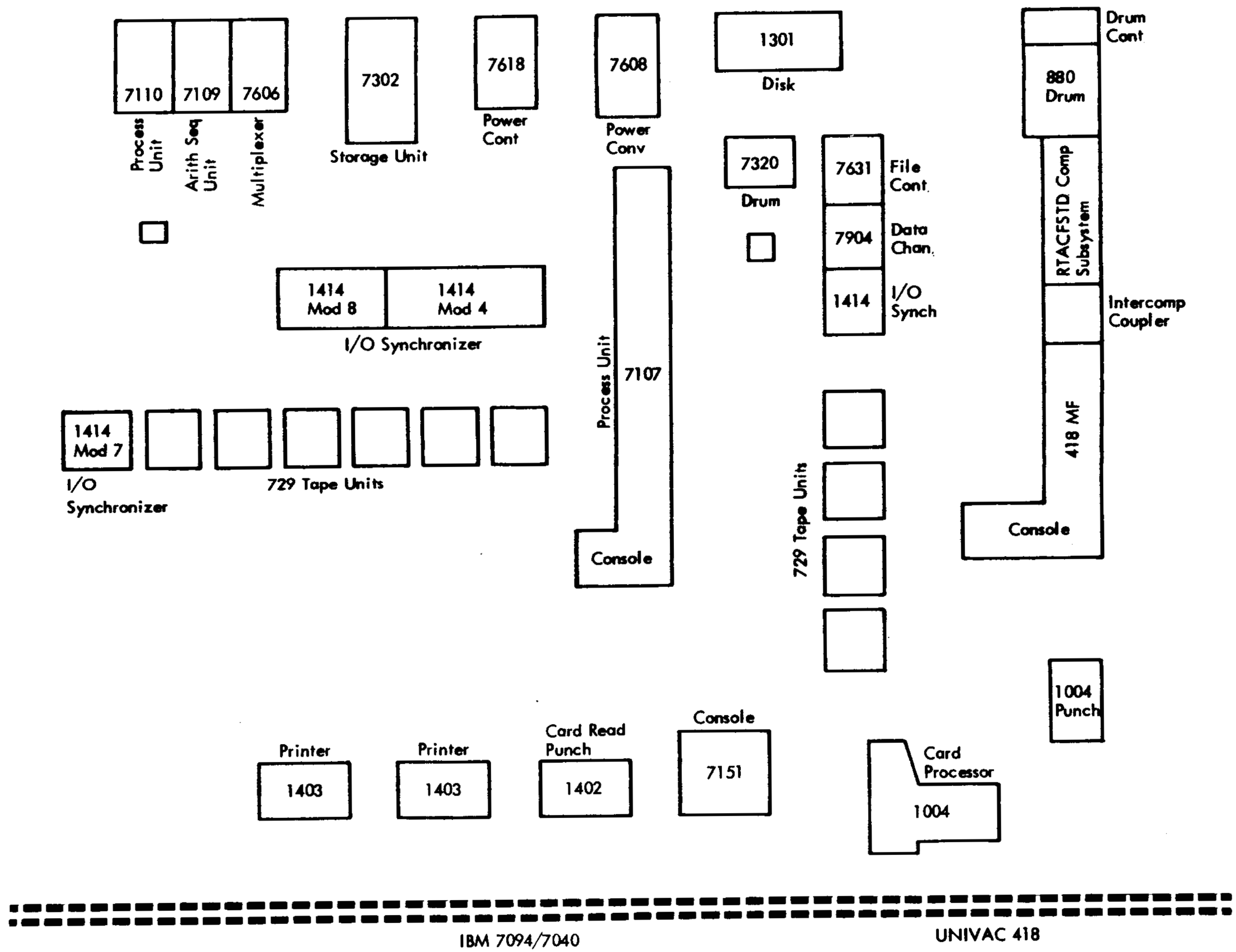


Figure 3. RTACF Backup Computer Facility

# 4. ORGANIZATIONAL STRUCTURE AND RESPONSIBILITIES

## 4.1 MISSION SUPPORT SECTION OF THE FLIGHT ANALYSIS BRANCH

The primary function of the Mission Support Section is the management, development, and manning of auxiliary inflight operational computing support. This support is provided in two ways. First, MSS supplies key personnel to staff the Flight Dynamics Staff Support Room which provides technical support directly to the flight controllers during both simulations and missions. Second, MSS has the responsibility for the RTACF. This includes coordination of the software computing requirements, development and verification of processors to be used in conjunction with various computer simulation programs, and coordination of the RTACF operations schedule for processor testing, simulations, and mission support. MSS does not generally provide all the individuals to staff the RTACF. Some personnel are obtained from Computation and Analysis Division (CAD), various mission planning agencies, and contractors.

## 4.2 RTACF WORKING GROUP

The activity that occurs to prepare the RTACF for simulations and real time mission support generally follows a uniform pattern. To achieve the necessary operational readiness, the Mission Planning and Analysis Division (MPAD) has formed the RTACF Working Group under the co-chairmanship of the Head, Mission Support Section and a member of the Flight Dynamics Branch of the Flight Control Division. The purpose of the RTACF Working Group is to obtain an efficient working relationship between the various agencies involved in generation, coordination, and implementation of the RTACF computational requirements. To achieve this, the RTACF Working Group is divided into RTACF Mission Teams (hereafter referred to as the Mission Teams) with the prime Trajectory Support Chief (TSC) for each mission as the Mission Team Leader. Each Mission Team is composed of representatives from the following:

Mission Planning and Analysis Division

Flight Analysis Branch
Mission Analysis Branch
Rendezvous Analysis Branch
Guidance and Performance Branch
Mathematical Physics Branch
Flight Software Branch

Flight Control Division

Computation and Analysis Division

Certain selected members of each Mission Team along with other designated personnel will staff the RTACF and the RTACF-related positions in the FDSSR.

## 4.3 RTACF MISSION TEAMS

The Mission Support Section is responsible for the flight support readiness of the RTACF. To achieve this readiness, the MSS through the Mission Teams headed by the Trajectory Support Chiefs, will coordinate the RTACF software requirements, computer processors to be used, processor verification, mission trajectory limit and information lines, simulation and mission constants, and work schedules. The manner in which these functions are carried out is described in subsequent sections of the OSP. Each Mission Team begins to meet about eight months before the scheduled launch date according to the following typical schedule:

| From | To | Frequency |
|---|---|---|
| T-8 months | T-6 months | monthly |
| T-6 months | T-3 months | twice a month |
| T-3 months | T-6 weeks | weekly |
| T-6 weeks | T-0 | as required |

The TSC notifies each team member in advance as to the meeting time, place, and agenda. After the meeting, the TSC publishes minutes of the meeting, where appropriate, in the form of a memorandum. This memorandum documents all official action item and new software requirements specified for the RTACF.

## 4.4 RTACF OPERATIONAL SUPPORT TEAMS

The teams that man the positions in the FDSSR and RTACF are not appointed until approximately two months before the scheduled launch date. Although several members of the team will have participated in the actual mission planning and may have been members of the RTACF Mission Team, the operational support team first functions as a group during the RTACF simulations. Specific team member duties are listed in Section 5.

# 5. RTACF OPERATIONAL PROCEDURES

## 5.1 GENERAL

The RTACF interfaces with the Mission Operations Control Room (MOCR) through the Flight Dynamics Staff Support Room. Mission Support Section personnel or their designated representatives staff the following positions within the FDSSR:

- Trajectory Support Chief
- Assistant Trajectory Support Chief
- Mission Consultant

The Trajectory Support Chief and his assistant provide the operational continuity necessary between the MOCR, FDSSR, and RTACF. The mission consultants provide detailed technical support to the TSC. They are generally the individuals who have planned and analyzed the mission and are therefore thoroughly familiar with it. On the other hand, they are not necessarily familiar with the flight control team and RTACF operational procedures, because usually different individuals plan and analyze each flight. Consequently, the same mission consultants would not staff the FDSSR every mission. The Trajectory Support Chief and Assistant positions are, however, staffed with those individuals having gained operational experience through participating with the flight control team and the RTACF during many simulations and missions.

## 5.2 FLIGHT CONTROL/RTACF OPERATIONAL INTERFACE

Routine problems requiring RTACF support are discussed between the requesting flight controllers and the Trajectory Support Chief or his assistant. Each mission consultant monitors displays and flight controller discussions related to his speciality so that he can provide timely technical support to the Trajectory Support Chief. Should problems arise during the flight about which the flight controllers have detailed technical questions, the mission consultant may communicate directly with the flight controllers; however, routine problems are directed to the Trajectory Support Chief. All requests for RTACF support (whether resulting indirectly through the mission consultants or directly by the flight controllers) are made to the Trajectory Support Chief. In this manner requests from the flight controllers for RTACF support are assigned priorities based on the status of the mission and by mutual agreement between the flight controller and the Trajectory Support Chief. As a result, the activities of the RTACF are intelligently scheduled and the overall effectiveness of the support is increased.

### 5.3 RTACF POSITIONS AND FUNCTIONAL OPERATION

The RTACF is staffed with three 8-hour shifts consisting of the following positions:

- ACR Chief
- Engineers
- Programmer Consultants
- Engineer's Aids
- Run Coordinators
- Key Punch Operators

All requests for support are directed to the ACR Chief through the Trajectory Support Chief or assistant. The ACR Chief's role is primarily that of a communicator and coordinator. In this capacity he unifies and schedules the activities of the individuals and facilities assigned to the RTACF to ensure a timely and successful response to the requests from the Trajectory Support Chief. Operational experience is supplied by the ACR Chief who is experienced with RTACF and FDSSR procedures and who is generally familiar with the capabilities of the processors employed.

Normally, engineers who have helped design and simulate a mission are requested to support the RTACF operation. Generally, this involves adapting the processors they used in planning and analyzing the mission to the requirements of the RTACF operation. Programming support for this effort as well as support during the flight is supplied by CAD. Once the processors are adapted, the engineer familiarizes the other shift personnel in their use, and then supports the preflight simulations and flight. The engineers associated with the RTACF operate through the ACR Chief; however, provisions are made to enable the engineers to communicate directly with the mission consultants in the FDSSR about detailed technical problems. This is not, however, a normal line of communication.

Figure 4 shows the functional interface between the MOCR, FDSSR, and RTACF. The solid lines indicate lines of direct action and represent the normal flow of communication or consultation. When necessary, the mission consultants can communicate directly with the flight controllers in the MOCR and specialty engineers in the RTACF as indicated by the dashed lines in the figure. However, all requests for support must be channeled through the Trajectory Support Chief.

## 5.4 TYPICAL DUTIES INVOLVED IN THE RTACF OPERATION

The following sub-sections enumerate typical duties of each position directly associated with the RTACF operation.

### 5.4.1 Trajectory Support Chief and Assistant

a) Determine and report RTACF readiness at the beginning of each shift.

b) Monitor pertinent flight control displays and communications.

c) When appropriate, advise flight controllers in making real time decisions.

d) Provide the ACR Chief with necessary input data.

e) Determine and assign priority to flight control requests for RTACF support during simulations and missions.

f) Evaluate and transmit RTACF computing results to the appropriate flight controller.

g) Record all requests for RTACF support in the log book.

h) Direct the RTACF to perform real time studies.

i) Coordinate the configuration of RTACF support equipment.

j) Enforce RTACF procedures.

k) Compile and verify the constants and trajectory data used in the RTCC and RTACF.

l) Provide necessary data to the Postflight Observers.

m) Provide data to the Federation Aeronautique International representative to be used in establishing international aerospace records.

n) Provide NORAD with real time state vectors and inform them of any change in the mission plan.

o) Coordinate the displaying of RTACF predicted footprint and landing points to the MOCR during entry.

p) Direct the activities of the engineer's aids assigned to the FDSSR.

q) Brief succeeding shift in FDSSR on the status of the mission and problem areas.

5.4.2 Mission Consultant

a) Monitor flight control displays and communications associated with specialty.

b) Provide technical support to Trajectory Support Chief and flight controllers and when required to the RTACF specialty engineer.

5.4.3 ACR Chief

a) Determine and report RTACF readiness at the beginning of each shift.

b) Keep the FDSSR on the monitor at all times.

c) Record all requests for RTACF support in the log book.

d) Enforce TSC's established priorities of work within the RTACF.

e) Maintain status of the jobs being processed.

f) See that detailed output data is transmitted to the FDSSR and to flight control via TV or engineer's aids.

g) At request of the FDSSR or the RTACF engineer, arrange direct conference between RTACF engineer and his counterpart in the FDSSR.

h) Notify in advance the appropriate computer supervisor (ACR, Building 12, or RTCC) when additional computer support is required. Additionally notify the appropriate computer supervisor of the lengths of time support is not likely to be required.

i) Brief the succeeding shift ACR Chief on the status of the mission, computer support, problem areas, etc.

j) Compile and update the telephone numbers where each member of the shift can be reached.

k) Enforce RTACF procedures.

5.4.4 Engineer in the ACR

a) Is primarily responsible for a processor or group of processors that apply to a certain portion of the flight, i.e., launch aborts, orbital maneuvers, entry, etc., and is generally familiar with all processors.

b) Complete the preprinted standard coding form for the key punch operator.

c) Assemble input deck and check for key punch and setup errors.

d) Submit job to machine operator and monitor the on-line output. If output is printed off-line, the CAD run coordinator waits for the output and returns it to the engineer.

e) Check the output and submit the results to ACR Chief for transmission to the FDSSR.

f) Monitor the flight control displays via the television viewers.

5.4.5 Program Consultant

a) Be available to "trouble shoot" jobs that fail.

b) Be available to answer questions concerning deck setup, program logic, and computer system operations.

c) Maintain and modify, as necessary, subroutines in the binary package of the real time mission tape.

d) Make verification runs whenever constants, logic, or formulations in the programs have been modified.

e) Provide up-to-date listings of the source decks for the subroutines in the binary package of the real time mission tape.

f) Maintain and supply FDSSR and RTACF engineers with up-to-date listings of the input data decks stored on tape.

5.4.6 Engineer's Aid

a) Collect and identify state vector data from teletype and UNIVAC 1004.

b) Plot the results from parametric studies conducted during the mission.

c) Fill out detailed output data forms and transmit them to the FDSSR and FMOCR either personally or via the television camera.

d) Other duties as assigned by the TSC or ACR Chief.

5.4.7 CAD Run Coordinator

a) Submit input sheets prepared by the engineer to the key punch operator and then checks for key punch errors.

b) When output is printed off-line, the CAD run coordinator waits for the output and returns it to the engineer.

c) When output is printed on-line, the CAD run coordinator remains with the ACR Chief to relay messages to the engineer who is monitoring the on-line printer.

d) Identify and bind output.

e) Coordinate with ACR Chief to alert machine operator to upcoming jobs.

f) Other duties as assigned by the TSC or ACR Chief.

5.4.8 Key Punch Operator

a) Key punch input data from approved forms.

b) Check for key punch errors.

5.4.9 Mode I Launch Abort Specialist

The Mode I Launch Abort Specialist is an engineer located in Building 12 with the responsibility of supplying to the recovery personnel at the Kennedy Space Center (KSC) and the Manned Spacecraft Center (MSC) prelaunch estimates of spacecraft impact points for Mode I launch aborts based on the actual wind profile prior to launch. This wind profile is generated from measurements made by balloon releases and radar tracking at KSC. Balloons are released at T minus 330, 240, 120 and 60 minutes. The first three ballons are tracked for 55 minutes and the last is tracked for 10 minutes. It takes approximately 15 minutes to process each set of radar data and generate the wind profile for the particular balloon release. This wind profile is sent from KSC along a data transmission link to the Mode I Launch Abort Specialist in Building 12 at MSC. The wind profile is input into a processor from which the abort impact points are obtained. The DCS computer in Building 12 is used for the computation and it takes approximately 20 minutes to generate the impact points once the wind profile is received. The results are then sent to the Landing and Recovery Room in the Mission Control Center at MSC, and also back to KSC. The specialist is in communication with the ACR Chief by way of standard telephone lines. In the event of an abort during the first 100 seconds of the flight, he obtains the abort time from the ACR Chief and estimates an impact point using the most current wind profile.

## 5.5 PREFLIGHT SIMULATION PROCEDURES

### 5.5.1 RTACF Inhouse Simulations

Inhouse simulations (as opposed to flight control simulations) are initiated as soon as processors are adapted to RTACF usage. Work on setting up processors is initiated as soon as specific requirements are levied on the RTACF. Generally, most of the requirements for a mission are known months before flight. Prior to and during this period, engineers work closely with the programmer consultants, the Trajectory Support Chief and assistant, and the ACR Chief to develop the processors necessary to meet the RTACF requirements. Once processors have been adapted and verified they are listed and put on tape. This serves to maintain some control over the processors and at the same time minimizes the number of cards handled and read into the computer through the on-line card reader. In addition to the processors on tape, a number of processors for each mission phase are prepared to perform studies as required during the mission. These processors are not put on tape because they will be used infrequently, and because of the possibility of major changes being required in the input data to answer specific flight control questions.

The RTACF inhouse simulations range in comprehensiveness and formality from two or three team members practicing with the processors in the RTACF to a parallel simulation with certain areas of flight control and RTCC participating. These inhouse simulations serve to debug the processors and to familiarize each member with the RTACF operations, with the processors, and with the other individuals assigned to support the flight. The emphasis during this period is on becoming familiar with the processors and their capabilities and to a lesser degree on RTACF operational procedures.

### 5.5.2 Flight Control Simulations

Approximately 6 weeks prior to the flight a series of flight control simulations which simulate as realistically as possible the flight and possible contingencies are scheduled. These simulations generally are completed approximately 1 week before the flight, and provide the last opportunity for establishment and integration of procedures between the ACR, FDSSR, and MOCR and comparison of RTACF processor outputs with those from the RTCC programs. Therefore, the RTACF procedures must be enforced by the TSC and ACR Chief to identify problem areas that should be corrected prior to flight. All of the team members keep a record of problem areas that might be detrimental to the RTACF operation. A critique similar to and concurrent with the flight controllers is conducted by the team members to increase the efficiency and reliability of the RTACF operation.

During both the RTACF and flight control simulations, each of the three shift teams receives training. Since the inhouse simulations are somewhat informal, most of the training of the second and third shift teams is accomplished during these simulations. The first shift or prime team generally supports the flight control simulations but all of the requests for RTACF support along with the output generated is saved. Then the same problems are given to the other two teams and their results are compared with those generated by the prime team and the RTCC. Since these two teams are operating independently of the MOCR, the problems can sometimes be run in a fraction of the time required during the flight simulation.

Since the Trajectory Support Chief and assistant coordinate and direct the preflight as well as flight support activities, it is their responsibility to see that processors are checked out, personnel assigned to the flight are trained, facility support is available, and RTACF procedures are enforced.

## 5.6 FLIGHT SUPPORT PROCEDURES

The procedures developed and formalized prior to the flight are implemented and enforced during flight support to ensure the effectiveness and reliability of the RTACF operation. Under normal circumstances (as simulated before the flight) communications and data flow will be as briefly summarized here.

a) A request for RTACF support can originate either directly from flight control or indirectly from flight control via the mission consultant after discussion of a non-nominal problem.

b) After the Trajectory Support Chief or assistant receives the request, it is forwarded along with the necessary input data to the ACR Chief.

c) The ACR Chief receives the input data from the FDSSR and assigns the request to the responsible engineer.

d) The current or any specified state vector is obtained from the engineer's aid, who collects them from the RTCC via the teletype and UNIVAC 1004.

e) The responsible engineer fills out standard coding forms for key punch.

f) The run coordinator takes the input data to the key punch operator and returns the punched cards to the engineer.

g) The engineer assembles the input decks. If the output is printed on-line, he submits the deck to the machine operator and waits for the on-line output. The run coordinator relays messages to the engineer while he is in the machine room. If the output is printed off-line, he submits the input deck to the machine operator and monitors the running of the processor. After a successful termination of the run, the run coordinator waits for the off-line output and returns it to the engineer.

h) If the job should fail to run successfully and the engineer cannot determine the cause, the programmer consultant aids him in diagnosing the problem.

i) If the job runs successfully and the results are valid, the engineer submits the output to the ACR Chief who transmits the data to the FDSSR. The run is identified and given to the engineer's aid to file in the event additional output data is required.

j) If additional data is required from the run, the engineer's aid completes output forms and places them under the television camera or hand carries the information to the FDSSR.

k) After everyone is finished with the run, the run coordinator binds it into a folder and files it.

Note that this summary is typical for a single request with only one engineer responding to the ACR Chief. In reality there may be three to five engineers, depending on the complexity of the mission phase.

One of the most important functions of the RTACF is to respond to anomalies in the mission. Sometimes questions can be answered without a computer run, but more frequently computer runs are required. Often a run is required that can be made with minimum changes to the processor; sometimes it cannot be made without major modifications. When the later occurs, the existing processor is duplicated to preserve the original before modifications are made. No new procedures are required for these abnormal situations; however, the engineer will probably utilize the capability to communicate directly with the mission consultant in the FDSSR.

## 5.7 RTACF READINESS PROCEDURES

At the beginning of each shift and after having been briefed by the preceding shift's ACR Chief,and having checked in with the Trajectory Support Chief or assistant, the ACR Chief determines the status of the following:

a) That all of the shift team are present.

b) That up-to-date listings of all input data decks and tapes are available.

c) That all computing facilities providing RTACF support are functioning.

After making these assessments, the ACR Chief will report the status of the RTACF to the Trajectory Support Chief or his assistant and state the problems if it is not ready.

## 5.8 COMPUTER FACILITY PROCEDURES

As outlined in Section 3, one primary and two backup computer facilities are available for RTACF support. The only requirements imposed on otherwise standard computer operations procedures are the following:

a) Input data loaded into the computer through the on-line card reader.

b) Interruption of current job for priority computations or printout of output.

c) Keeping cognizant of RTACF activity so that normal non-RTACF jobs can be processed on a time-available basis.

d) Direct contact with engineers who may or may not be familiar with standard computer operations procedures.

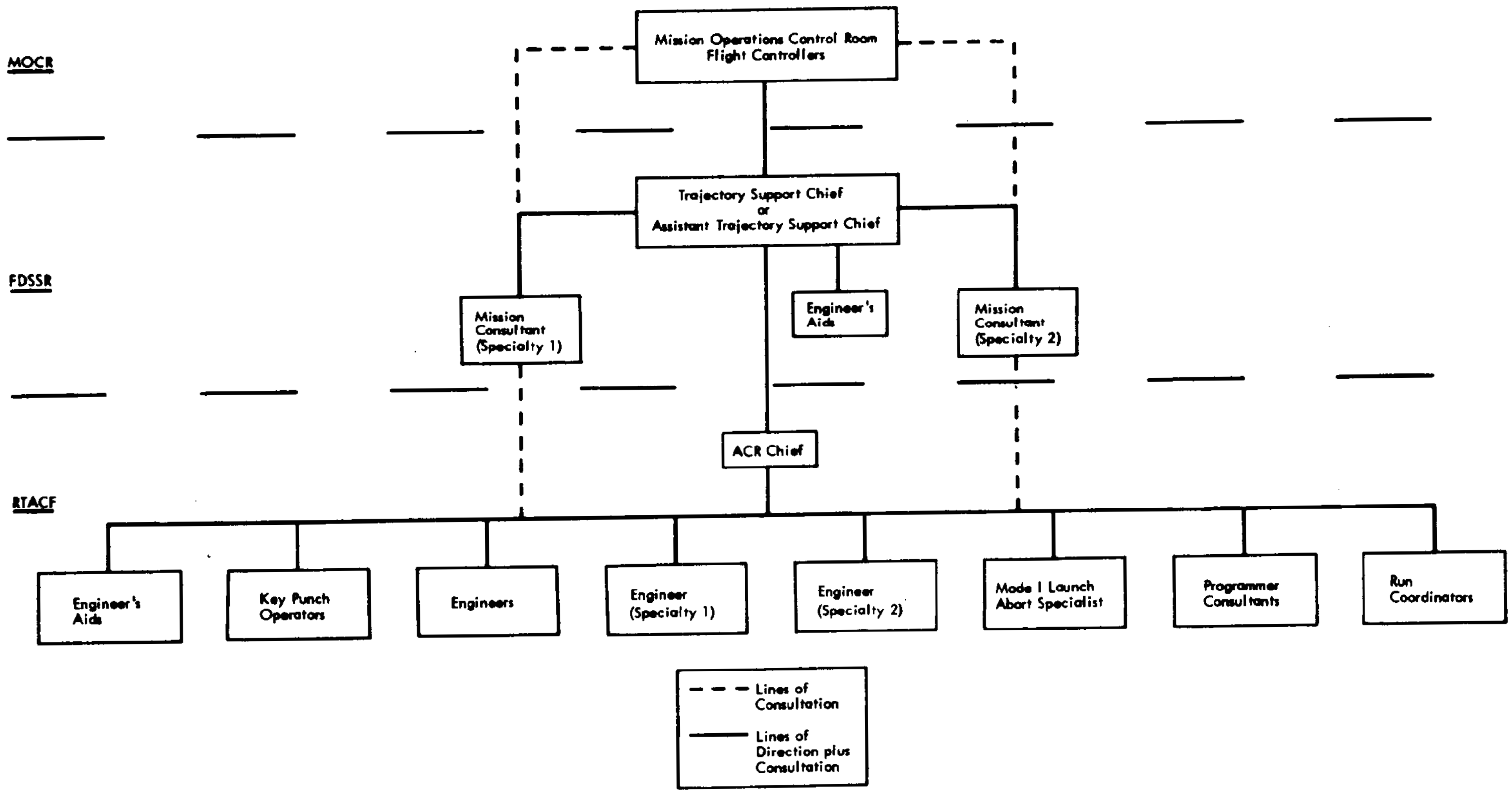


Figure 4. Functional Operation of the RTACF

# 6. PROCEDURES FOR IMPLEMENTING REQUIREMENTS FOR RTACF SUPPORT

## 6.1 GENERAL

Any organization within MSC which identifies potential requirements for computational support during a mission shall submit their requirements in writing prior to the mission to the Director of Flight Operations. If the organization is within the Flight Operations Directorate (FOD), the requirement shall be submitted to Chief, Flight Control Division (FCD). Once received, the requirement will be handled in accordance with the existing MSC Management Instruction "MSC Implementation of Inflight Operational Computing Support." Those requirements which are approved are forwarded to MPAD for incorporation into the RTCC or the RTACF.

Computing requirements which are assigned to the RTCC are turned over to Flight Software Branch (FSB), MPAD, and are handled under existing procedures. Requirements which are determined to be appropriate for the RTACF are turned over to the Mission Support Section, FAB, and are processed in accordance with the procedures outlined in this section.

## 6.2 IMPLEMENTATION OF REQUIREMENTS

Requirements which have been assigned to the RTACF for support are further assigned to the Mission Team for the particular flight involved. The Mission Team determines whether the requirement can be satisfied as stated, or, in the event that it cannot be, negotiates an acceptable alternative with the agency which has levied the requirement. Since many RTACF requirements call for generation of trajectory information used in mission planning, the computer program used to plan the mission is usually adapted for use in the RTACF by personnel from the Computation and Analysis Division with the help of the mission team. When this occurs, the programs are normally modified by removing option modes of operation, etc., which are not necessary for mission support and by changing output formats to reduce running times.

If the requirement is for other than trajectory information, the Trajectory Support Chief may request the originator of the requirement to supply a program. In the event that no computer program exists which can satisfy the requirement, the TSC will attempt to provide one by requesting the Flight Studies Section (FSS), MPAD, to coordinate through CAD the modification of an existing computer program or develop a new program with additional capability to meet the specified requirement. Another alternative is to have a contractor develop a program with the desired capability.

# 7. PROCEDURES FOR COORDINATING MISSION CONSTANTS

## 7.1 GENERAL

The Mission Support Section has been designated as the agency responsible for coordinating and managing the collection of constants used for mission simulation and mission support. Designation of a single MPAD group to consolidate all activity of this type is necessary to insure that data used in the RTCC, the RTACF, and the mission simulator are the same and are consistent with the spacecraft to be flown. This will insure consistent output results from independent sources for the same computation. Although the data are obtained from several sources at MSC and from numerous contractors, the official constants to be used in mission support will be collected and handled by the procedures outlined below. The Flight Software Branch is the agency responsible for the official publication of constants.

## 7.2 PROCEDURES

### 7.2.1 Prior to T-8 Weeks

During the early phases of the checkout of computer programs to be used in the RTCC, RTACF, or Apollo Mission Simulator (AMS), organizations should contact the Trajectory Support Chief to obtain current approved constants. The TSC will then provide the values, if known, or request them from the appropriate agency. Normally, these values will be taken from the Mission Modular Data Book (MMDB). However, unusual circumstances such as recently revised MMDB values or changes which have not yet been documented may result in different values for official constants. In some cases, values used to generate the Operational Trajectory or similar documents may be provided so that test cases can be run using consistent data. These values will be published via memorandum prior to the start of simulations.

### 7.2.2 T-8 Weeks and Subsequent

A T-8 weeks, T-4 weeks, and T-3 days, updated values of constants will be collected by the Mission Team and computer runs will be made to determine if these new values materially change the outputs of the processors being used. If significant changes occur, all organizations involved will be provided with an updated set of constants. If no significant changes result from these updated constants, the old values will continue to be used until launch day.

### 7.2.3 Launch Day Update

At approximately T-6 hours, the TSC will contact the necessary organizations to obtain the final values of constants for use in mission support. If necessary (as determined by check cases), these values will be inserted into RTACF programs and furnished to the RTCC Computer Supervisor for insertion into the RTCC programs. If updates become necessary during the mission, these will be handled in the same manner.

# 8. PROCEDURES FOR COORDINATION OF MISSION TRAJECTORY LINES

## 8.1 GENERAL

The Mission Support Section has been given the responsibility to coordinate and manage the data flow involved in the generation of nominal plotboard trajectory traces, information lines and limit lines for the RTCC, flight control ships, and remote sites. By designating a central point of contract, compatibility should be insured and collection of the necessary information in a timely manner should be enhanced. The procedures outlined below are followed where possible to provide the orderly collection of data.

## 8.2 PROCEDURES

### 8.2.1 Identification of Requirements

The RTACF Working Group Mission Team will normally meet at eight weeks prior to simulations to discuss requirements for mission trajectory lines. These will then be formally transmitted by the Chief, Flight Control Division, to the Chief, Mission Planning and Analysis Division, via a memorandum approximately 6 weeks prior to commencement of simulations.

### 8.2.2 Collection of Data

Upon receipt of the requirements memorandum, the Trajectory Support Chief will assign the appropriate requirements to the responsible agency through the various mission team members and will establish a due date consistent with the simulation schedule. Each team member will then collect the data and transmit it to the TSC via memorandum, including the constants used for computations, a tabulation of the quantities to be plotted and a display facsimile with the lines plotted. These will normally be required 4 weeks prior to the start of simulations.

### 8.2.3 Implementation of Trajectory Lines

When all inputs have been received, the TSC will compile the data package and transmit it via memorandum to the Flight Software Branch approximately 2 weeks prior to start of simulations. FSB will then implement these lines into the real time display system.

# 9. PROGRAMS USED IN THE RTACF

## 9.1 GENERAL

The programs used in the RTACF at present are largely those used during the mission planning effort. For the early Apollo flights, most of the RTACF processors are adaptations of the Manned Spacecraft Center General Electric Missile and Satellite System Program (SG-GEM) and the Apollo RTACF Rendezvous System Program (ARRS), since these two programs are now used almost exclusively for the preflight mission planning efforts. For later flights there will be others. The Apollo Reference Mission Program (ARMP) and the Abort to an Optimum Return Trajectory Program (ABORT) are two examples. Also, there will always be several specialized programs in the RTACF. These are usually small programs developed to fulfill some recurring requirements for which the larger programs cannot be adapted. Several of these programs, which were developed to support the Gemini missions, are already in the RTACF program library and will be used to support some of the Apollo missions.

## 9.2 THE MSC GENERAL ELECTRIC MISSILE AND SATELLITE SYSTEM PROGRAM

SG-GEM is a versatile high speed digital computer program originally developed by General Electric to simulate the flight of a missile or a satellite for the Space Task Group (predecessor of the Manned Spacecraft Center). So many development and modification changes have been made to the program by personnel of the Computation and Analysis Division since the original version that its name was changed from GE-MASS to SG-GEM in January of 1966.

The generality and flexibility of SG-GEM is derived from its ability to accept the spacecraft geophysical environment and configuration as input and from its ability to make all of the program capabilities available at any discrete point in a spacecraft trajectory. The spacecraft configuration is defined by the sequence of inflight events and the operations to be performed or initiated at each event. Depending upon the options selected by the user, the program can numerically integrate the equations of motion of a vehicle as a two-, three-, four-, or six-degree-of-freedom rigid body or as a point mass in any one of four available modes (normal mode, parameter mode, parameter iteration technique mode, and boundary value mode). When the program is used in the normal mode, it reads data, integrates the equations of motion to a specified end condition, and returns to read more data. In the parameter mode the program returns to a selected point in the normal trajectory and adjusts any single input parameter by linear interpolation and/or extrapolation to reach a given end condition. This mode is very helpful in performing parametric studies. The Parameter Iteration Technique (PIT) mode is really a variation of the parameter mode. In this mode the program may be used to iterate on any single parameter. The capability also exists to range a second parameter and repeat the iterative technique to again satisfy the specified end conditions. In the boundary value mode the program will return to a selected point in the normal trajectory and adjust up to six initial boundary parameters in order to satisfy the same number of required end conditions.

The program was originally written in FORTRAN II with some machine language (FAP) subroutines added for efficiency. However, a FORTRAN IV version with more machine language (SLEUTH) subroutines now exists for use on the UNIVAC 1108. Run time depends naturally on the program requirements.

During the early Apollo missions there may be as many as thirty different SG-GEM processors used in the RTACF. Each may be of a different degree of complexity and used for many different purposes. For example, the Apollo AS-204 flight requires nine different SG-GEM launch abort processors, fourteen SG-GEM deorbit and entry processors, two SG-GEM in-orbit maneuver calculation processors, and four general information processors. All of these are three-degree-of-freedom point mass simulations except for two of the entry processors which are four-degree-of-freedom point mass simulations and one entry processor which is a six-degree-of-freedom simulation. Three of these processors are guided (the Apollo AS-204 guidance scheme has been added to the simulation) while all others are unguided.

## 9.3 THE APOLLO RTACF RENDEZVOUS SYSTEM PROGRAM

The ARRS, which was developed by the Rendezvous Analysis Branch to solve rendezvous problems, is a group of processors built around a main routing program. It is not a generalized trajectory program such as SG-GEM but is a program designed to perform a set of specific calculations. For the early Apollo missions the program will contain the following processors:

a) Launch Window Processor - This processor computes the opening and closing of the plane change launch window based on the maximum $\Delta V$ available for the plane change.

b) Recommended Lift-off Time Processor - This processor recommends a lift-off time based on a preflight chosen rendezvous plan.

c) Targeting Processor - This processor computes the Apollo launch vehicle targeting quantities which define the target plan for the guidance equations.

d) Rendezvous Planning Table Processor - This processor will compute rendezvous plans based on flight control inputs.

e) Mission Planning Table Processor - This processor will superimpose a finite burn on a set of impulsive elements and simulate the on-board method of executing the maneuvers.

f) Two-Impulse Terminal Phase Processor - This processor computes terminal phase maneuvers to complete the rendezvous plan. It also computes a pair of maneuvers to give a certain relative position between vehicles.

g) Coelliptic Sequence Processor - This processor computes coelliptic sequence rendezvous maneuver plans.

h) Relative Motion Digitals - This processor computes relative motion quantities between two vehicles.

i) General Purpose Maneuver Processor - This processor can compute 32 different kinds of orbital maneuvers depending upon the particular request from flight control.

The ARRS uses the Analytic Ephemeris Generator Program (AEG) for orbit propagation. The AEG provides a rapid and accurate mathematical technique of orbit prediction in terms of the classical Keplerian elements. The prediction scheme consists of a series of drag-free equations which compute the effects of the earth's oblateness on an orbiting satellite, and a second series of equations which add the effects of atmospheric drag. The AEG as used in the ARRS has been found to be as accurate as a program using a numerical integration method for predicting future satellite positions and has the advantage of being more rapid in its calculations.

The rendezvous logic in the ARRS is nominally the same as the logic in the RTCC. When this is the case, the ARRS is used in the RTACF as a backup to the RTCC and to plan alternate or off-nominal missions. There have been times, however, when the RTCC has not had time to incorporate the most current rendezvous logic into their master programs, and thus the ARRS has become the only source for rendezvous information.

# 10. VERIFICATION PROCEDURES FOR RTACF PROCESSORS

## 10.1 GENERAL

Because of the variety of computer programs used in the RTACF, there are no specific verification procedures which are universally applicable. Instead, each processor and the program which it operates are debugged and verified via the most appropriate means. Since most processors are prepared by the RTACF Mission Team members who will use them during mission support, the entire processor development cycle contains an integrated verification effort.

## 10.2 VERIFICATION CRITERIA

After any necessary program modifications have been made and debugged by the Computation and Analysis Division, the mission team member makes a run with the processor during an inhouse simulation using test cases which are available. The cases used generally fall into the following four groups:

### 10.2.1 Mission Planning Results

Frequently the processors can be verified using test cases obtained from the Operational Trajectory, alternate missions, and abort documents. There are also other special mission planning studies which can be used for verification purposes. These are usually in response to a request for a special study from some particular MSC agency (e.g. flight control) and are documented in the form of a memorandum.

### 10.2.2 RTCC Results

In many instances the Flight Software Branch will request the RTACF to verify results obtained from the RTCC. Using the input data supplied with the request, several test cases are run and the results of the RTACF and RTCC are compared. Since these results are generated by completely independent programs, agreement between the two generally constitutes verification.

### 10.2.3 Hand Calculations

In certain cases, comparable programs do not exist in the RTCC or elsewhere and hand calculations must be used to verify that the processor operates correctly. Use of this technique is normally limited to the less complicated processors due to time constraints.

### 10.2.4 Feasibility of Results

In some cases, the only verification possible is a general judgement of the results based on experience and observation of several test cases. Verification in this instance is merely a check of the processor output to see that discontinuities and unreasonable results are not obtained.